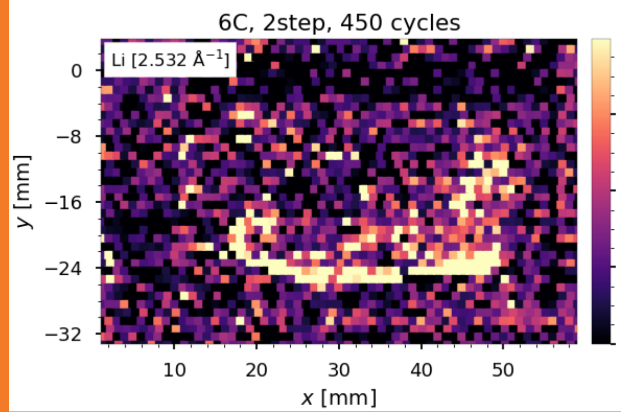
BAT338

EXTREME FAST CHARGING CELL DEVELOPMENT OVERVIEW



VENKAT SRINIVASAN
Argonne National Lab

SAMUEL GILLARD
Department of Energy

This presentation does not contain any proprietary, confidential, or otherwise restricted information

June 12, 2019
Crystal City, VA

OVERVIEW

Timeline

- Start: October 1, 2017
- End: September 30, 2021
- Percent Complete: 37%

Barriers

- Cell degradation during fast charge
- Low energy density and high cost of fast charge cells

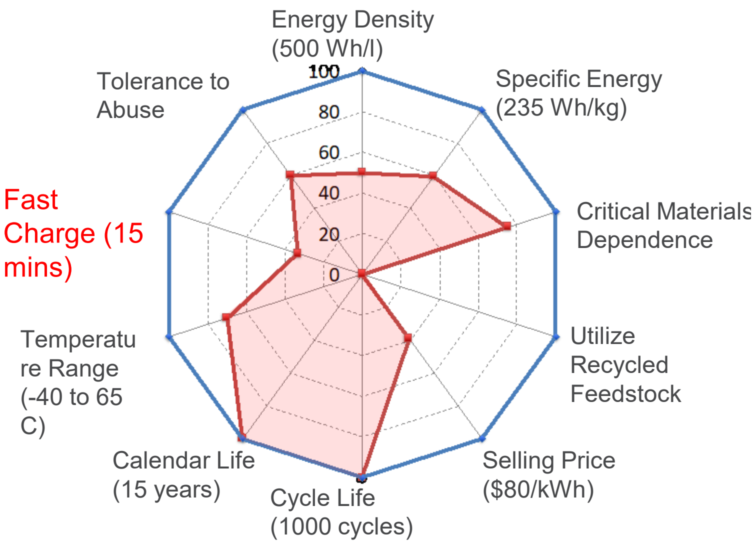
Budget

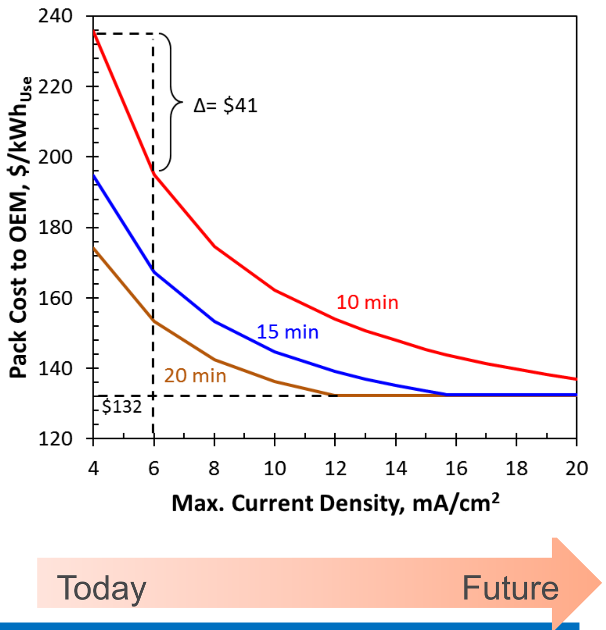
- Funding for FY19 – 6390k
  - ANL – 2400k
  - NREL – 1600K
  - INL – 440K
  - SLAC – 1000K
  - LBNL – 950K

Partners

- Argonne National Laboratory
- Idaho National Laboratory
- Lawrence Berkeley National Lab
- National Renewable Energy Laboratory
- SLAC National Accelerator Lab

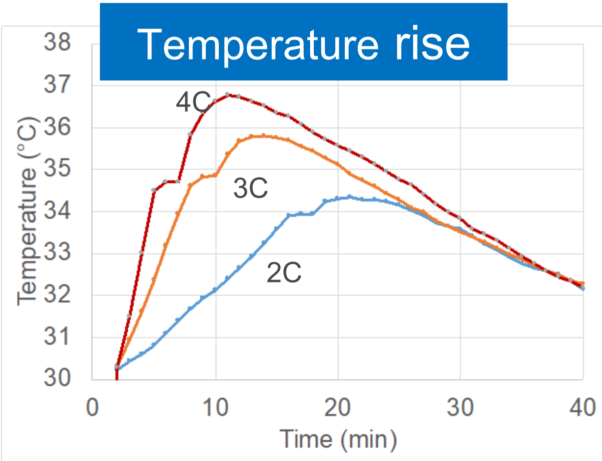
RELEVANCE: FAST CHARGE REMAINS AN ISSUE FOR WIDESPREAD ADOPTION OF EVS

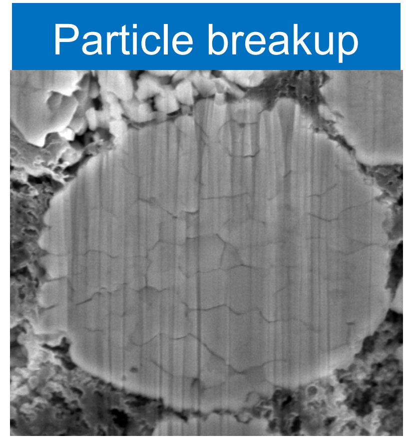


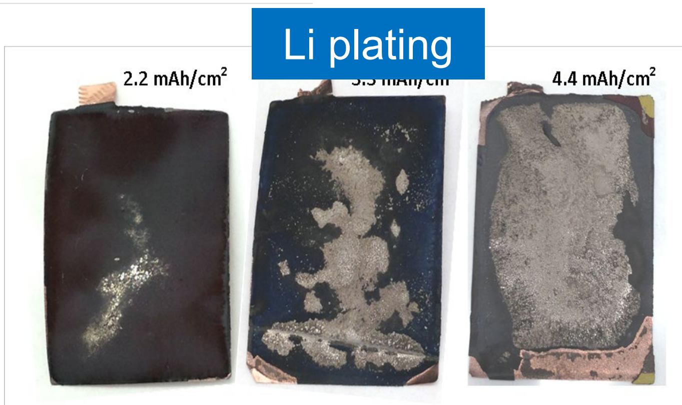


Fast charging a major issue. While fast charge cells exist, they are cost prohibitive or have poor life

RELEVANCE: WHAT LIMITS FAST CHARGE?

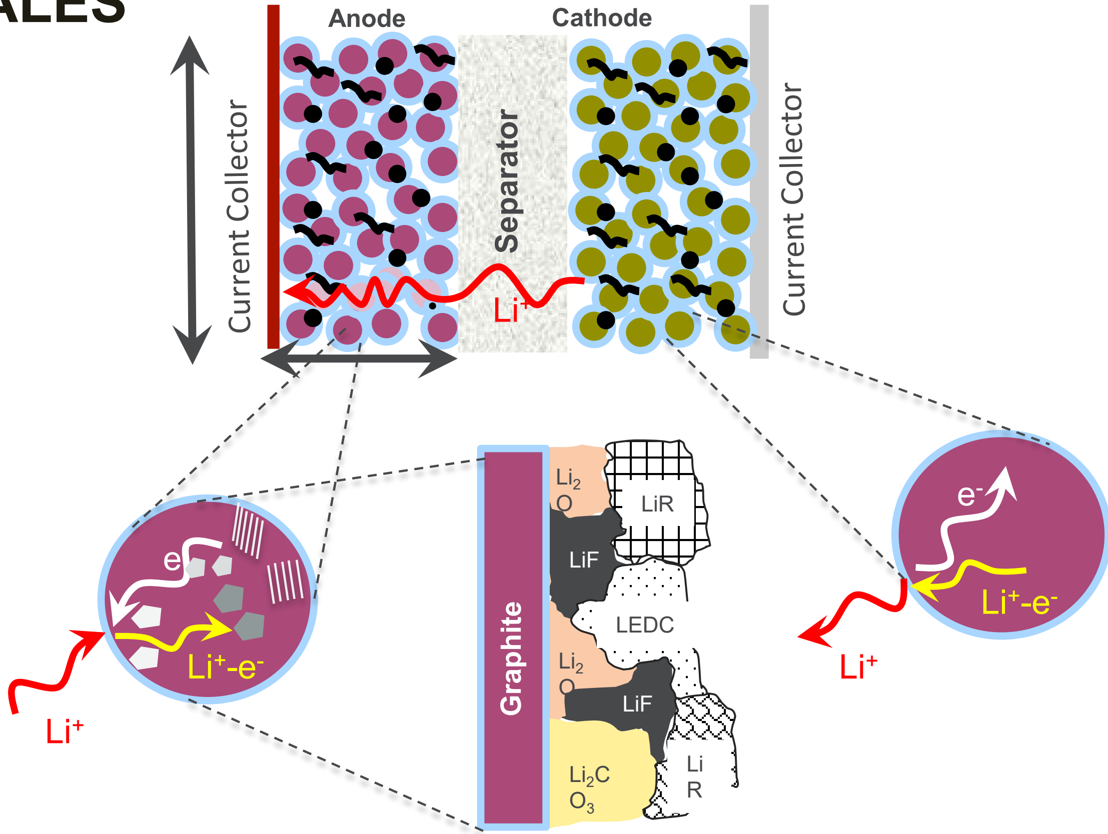






Li plating remains a critical issue

RELEVANCE: CHALLENGES AT MULTIPLE SCALES



QUESTIONS TO HELP MAP THE PROBLEM

1. How does the anode design (loading, porosity…) influence the propensity for Li plating? **BAT339**

2. How does the charging protocol and extended cycling impact degradation (anode *vs.* cathode) during fast charge? **BAT340**

3. Can we quantify the bottleneck at the electrode scale? Can we start to examine solutions to enable fast charge? **BAT371**

4. How important are local heterogeneities in determine the propensity for Li plating? Does Li transport in graphite depend on charging rates? **BAT383**

5. Can we detect Li plating *in situ?* And at what scale? **BAT384**

COLLABORATION ACROSS LABS AND UNIVERSITIES

Argonne National Laboratory: Cell and electrode design and building, performance characterization, post-test, cell and atomistic modeling, cost modeling

Berkeley Lab: Li detection, electrode architecture, diagnostics

Idaho National Laboratory: Performance characterization, failure analysis, electrolyte modeling and characterization, Li detection

NREL National Renewable Energy Laboratory: Thermal characterization, life modeling, micro and macro scale modeling, electrolyte modeling and characterization

SLAC National Accelerator Laboratory: Li detection, novel separators, diagnostics

CONTRIBUTORS AND ACKNOWLEDGEMENTS

Aashutosh Mistry
Andy Jansen
Abhi Raj
Alison Dunlop
Andrew Colclasure
Antony Vamvakeros
Aron Saxon
Bryan McCloskey
Bryant Polzin
Chuntian Cao
Daniel Abraham
Daniel Steingart
Dave Kim
David Robertson
David Wragg
Dean Skoien
Dennis Dees
Donal Finegan
Eongyu Yi
Eric Dufek
Francois Usseglio-Viretta
Francesco De Carlo
Guoying Chen
Hakim Iddir
Hans-Georg Steinrück
Hansen Wang
Ilya Shkrob
Ira Bloom
Jiayu Wan
Jianming Bai
Johanna Nelson Weker
John Okasinski
Juan Garcia
Kamila Wiaderek
Kandler Smith
Kaushik Kalaga
Kevin Gering
Marca Doeff
Marco DiMichiel
Marco Rodrigues
Matt Keyser
Michael Evans
Michael Toney
Nancy Dietz Rago
Nitash Balsara
Olaf Borkiewicz
Partha Mukherjee
Partha Paul
Paul Shearing
Pavel Shevchenko
Pierre Yao
Ravi Prasher
Ren Yang
Robert Kostecki
Ruqing Xu
Ryan Jackman
Sang Cheol Kim
Sangwook Kim
Sean Wood
Seoung-Bum Son
Shabbir Ahmed
Shriram Santhanagopalan
Steve Trask
Tanvir Tanim
Uta Ruett
Venkat Srinivasan
Victor Maroni
Vince Battaglia
Vivek Thampy
Wei Tong
Weijie Mai
Wenxiao Huang
William Huang
Yanying Zhu
Yi Cui
Zhenzhen Yang

Argonne NATIONAL LABORATORY
BERKELEY LAB Lawrence Berkeley National Laboratory
INL Idaho National Laboratory
NREL NATIONAL RENEWABLE ENERGY LABORATORY
SLAC NATIONAL ACCELERATOR LABORATORY

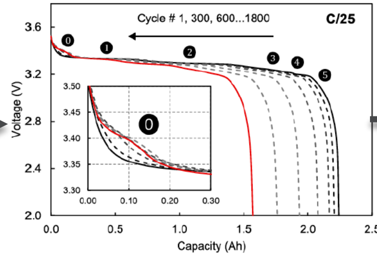
Support for this work from the Vehicle Technologies Office, DOE-EERE – Samuel Gillard, Steven Boyd, David Howell

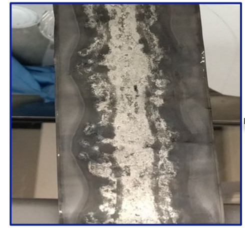
ESRF The European Synchrotron
UCL
PURDUE UNIVERSITY

XCEL eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
VEHICLE TECHNOLOGIES OFFICE

APPROACH: COMBINE CUSTOM DESIGNED ELECTRODES WITH ADVANCED CHARACTERIZATION AND MULTISCALE MODELING

Leverage the strengths among the partner institutions





Cells with different designs

- Different graphite's
- Different loading
- Cells with and without reference electrode

Fast charge testing and electrochemical diagnostics

- Different charge rates.
- Short vs. long term cycling
- Coulombic efficiency
- Electrochemical signatures of plating

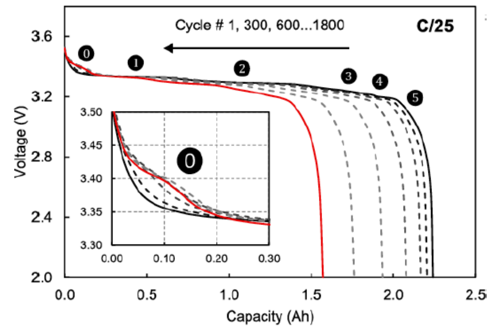
Characterization: in situ and post test.

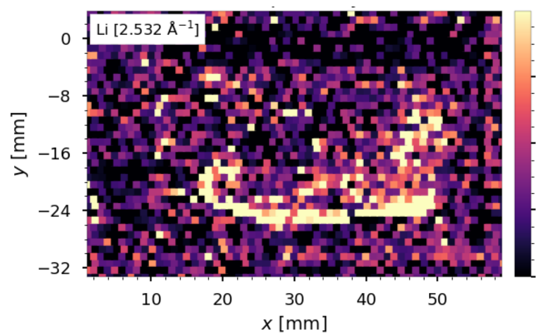
- X-ray-based: reaction distribution
- Li detection: SEM, XPS.
- SEI detection: Raman, FTIR, XPS, HPLC
- Particle cracking: XRD, SEM

DETECTING LI PLATING: A CHALLENGE

In situ methods. Question: How close to nucleation can we detect plating?

- Electrochemical (coulombic efficiency, capacity fade, electrochemical signatures)
- Reference electrode methods
- Acoustic
- Thermal
- X-ray-based analysis
- Gas evolution
- …



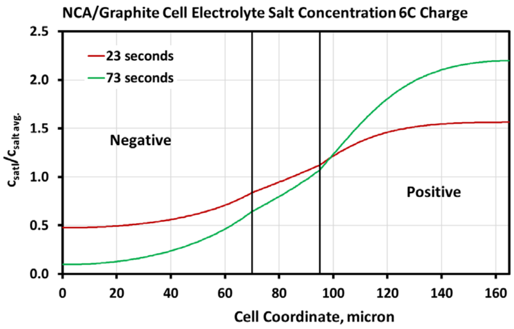


Detecting Li plating in situ at its initiation remains a key challenge

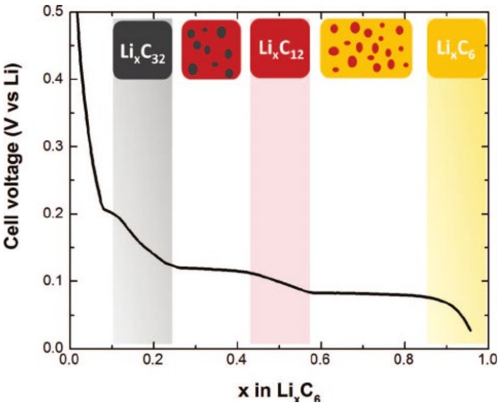
XCEL eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
VEHICLE TECHNOLOGIES OFFICE

MODELING AT DIFFERENT SCALES TO IDENTIFY LIMITATIONS

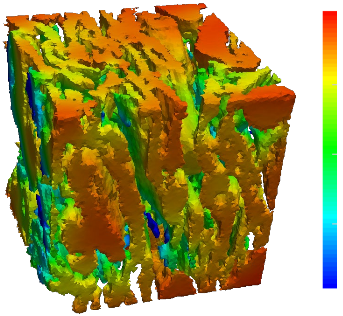
Electrode level effects



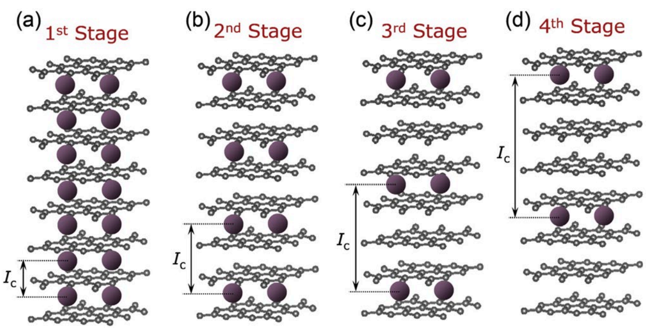
Particle-scale issues



Microstructure scale effects

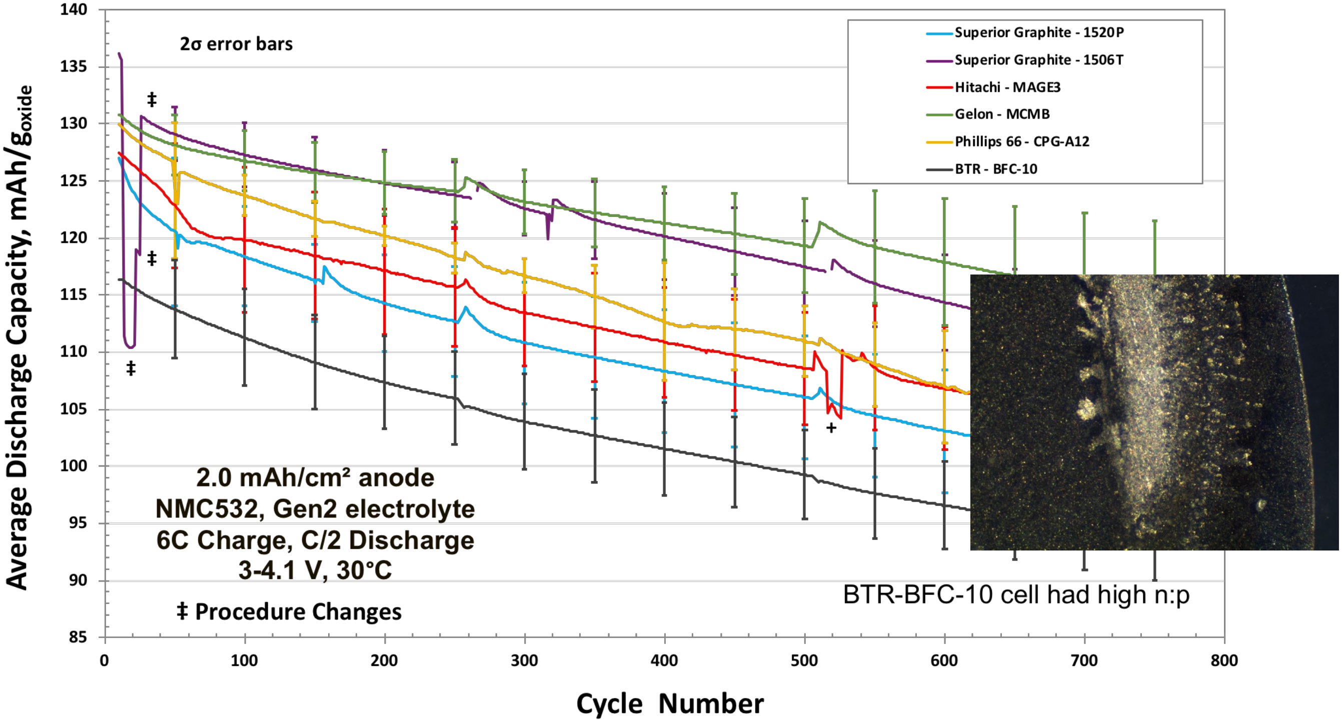


Graphite layer scale



ANODES CYCLE WELL…EVEN WHEN THEY PLATE

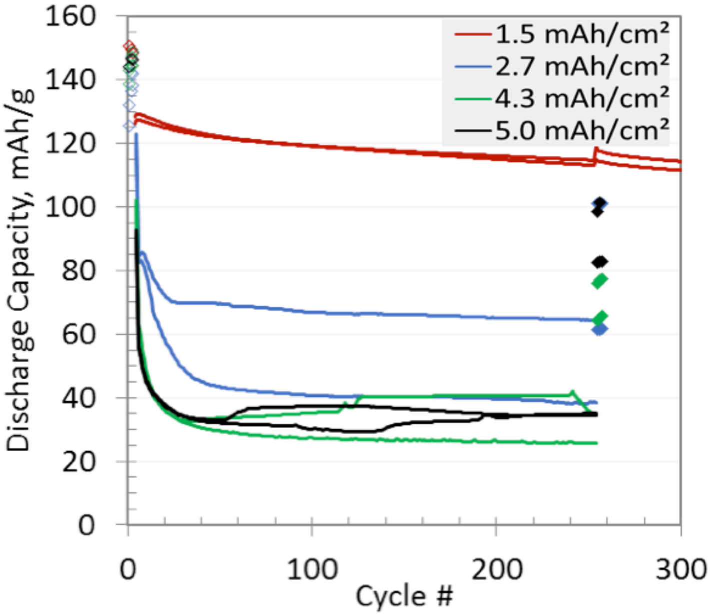
6 C charge on 2 mAh/cm² anode cells

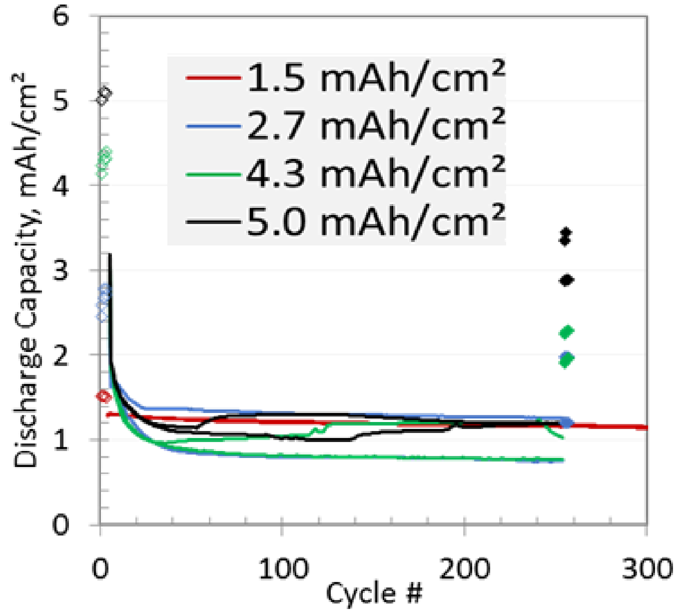


Thin cells cycle well. And fade seems similar with different graphite's and on CMC-SBR and PVDF binder cells

WHAT HAPPENS WHEN WE INCREASE THE LOADING?

Conoco Philips GCP-A12



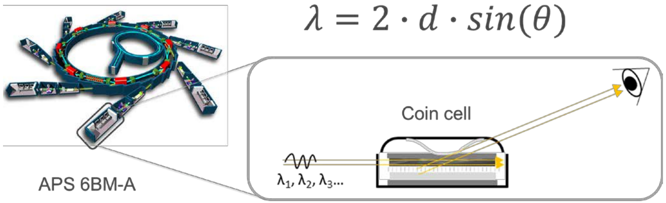


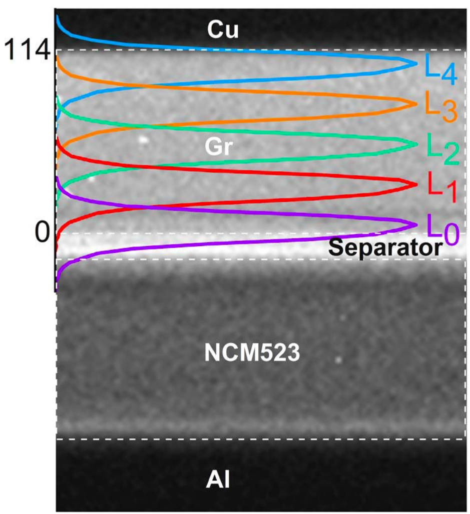
Results suggest the need to examine the reaction distribution in the porous anode

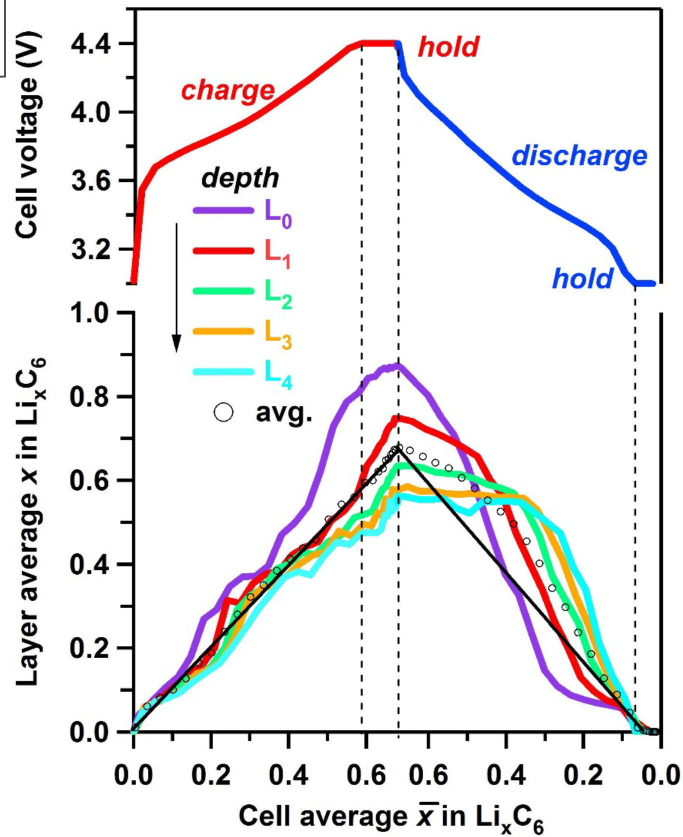
IN SITU SYNCHROTRON EDXRD DETECTION OF REACTION DISTRIBUTION

Dan Abraham, *Energy & Environmental Science* 12.2 (2019): 656-665.

$$\lambda = 2 \cdot d \cdot sin(\theta)$$

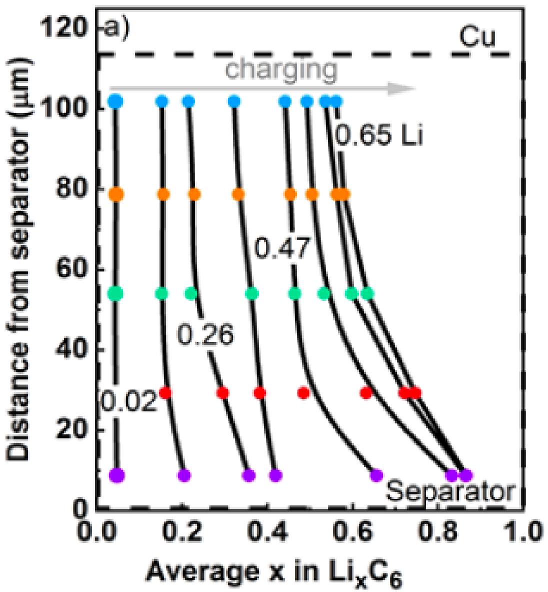


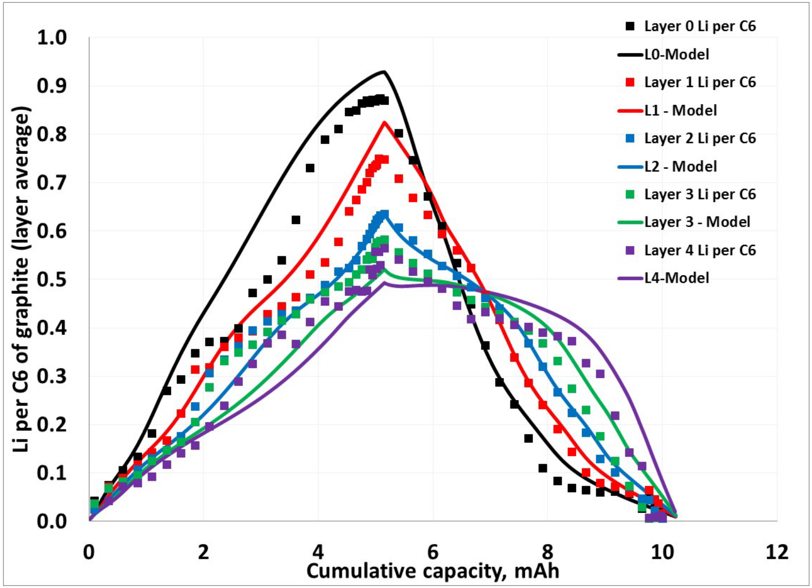




MODELS SHOW REASONABLE PREDICTIVE CAPABILITY

1 C rate



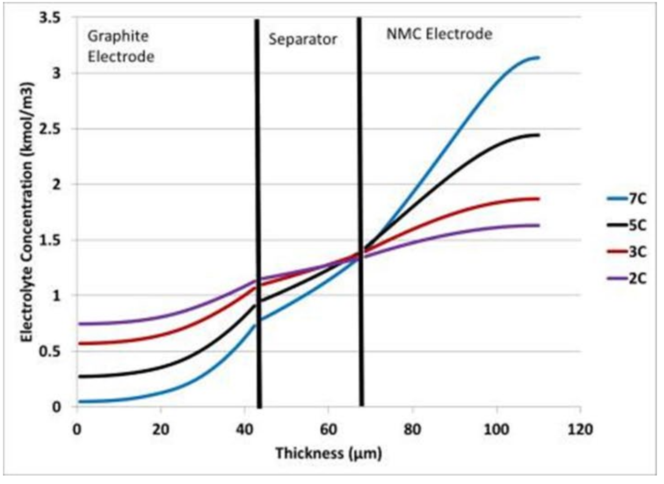


MODEL PROVIDES INSIGHTS INTO OBSERVATIONS

Low Electrode Loading

1.5 mAh/cm^2 cathode (42 μm)

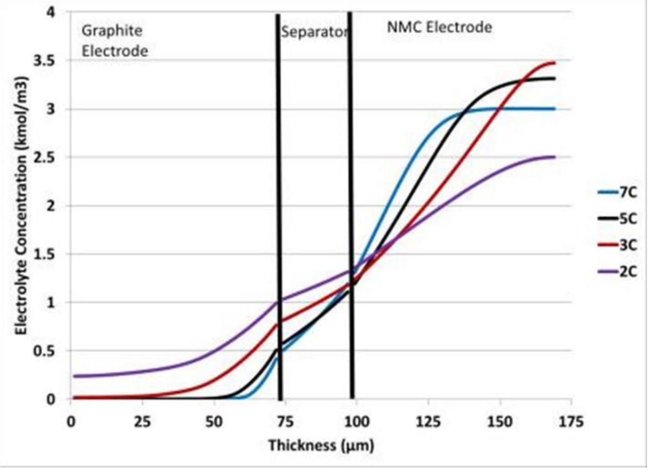
1.84 mAh/cm^2 anode (43 μm)



Medium Electrode Loading

2.5 mAh/cm^2 cathode (71 μm)

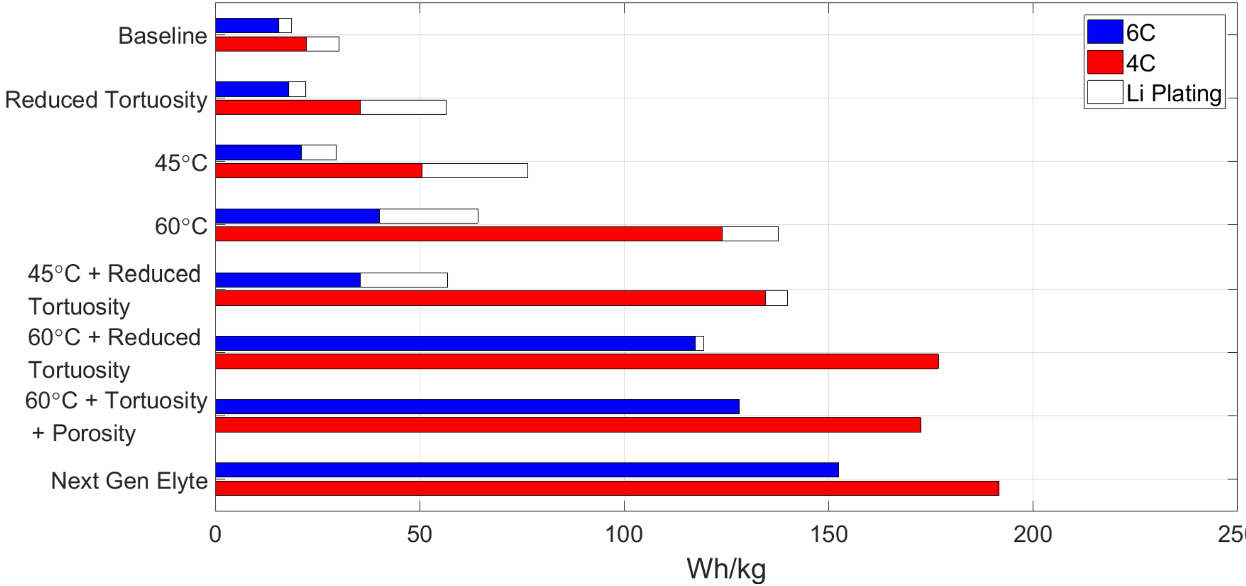
3.07 mAh/cm^2 anode (87 μm)



Fast charging will require enhancing the electrolyte transport in the porous electrode

MODELS SHOW IMPACT OF DIFFERENT APPROACHES

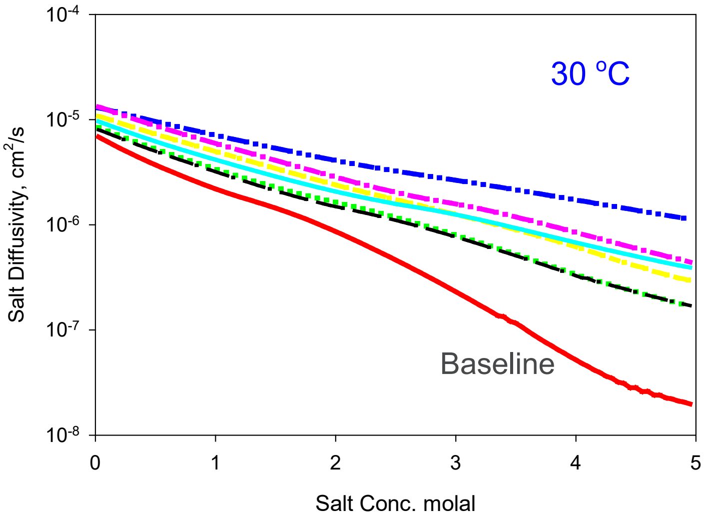
4 mAh/cm^2 (230 Wh/kg cell; 110 micron electrodes)

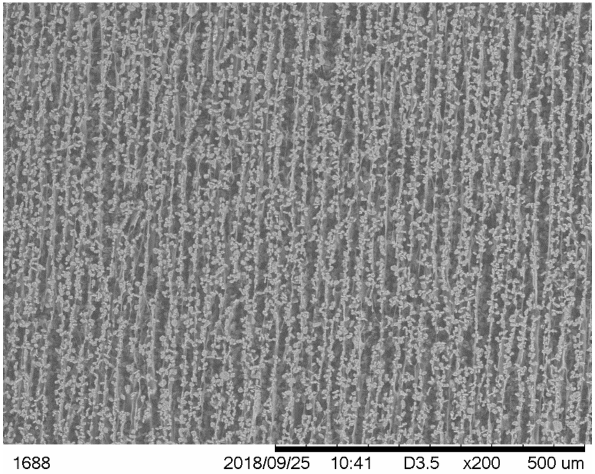


- Next Gen Electrolyte = 2X ionic conductivity, 4X diffusivity, and transference number increased by 0.15

Need a combination of approaches

WE ARE NOW EMBARKING ON TESTING THESE PREDICTIONS





Higher transport property electrolytes

Reducing tortuosity in the anode

HETEROGENEITIES BECOMING A FOCUS AREA

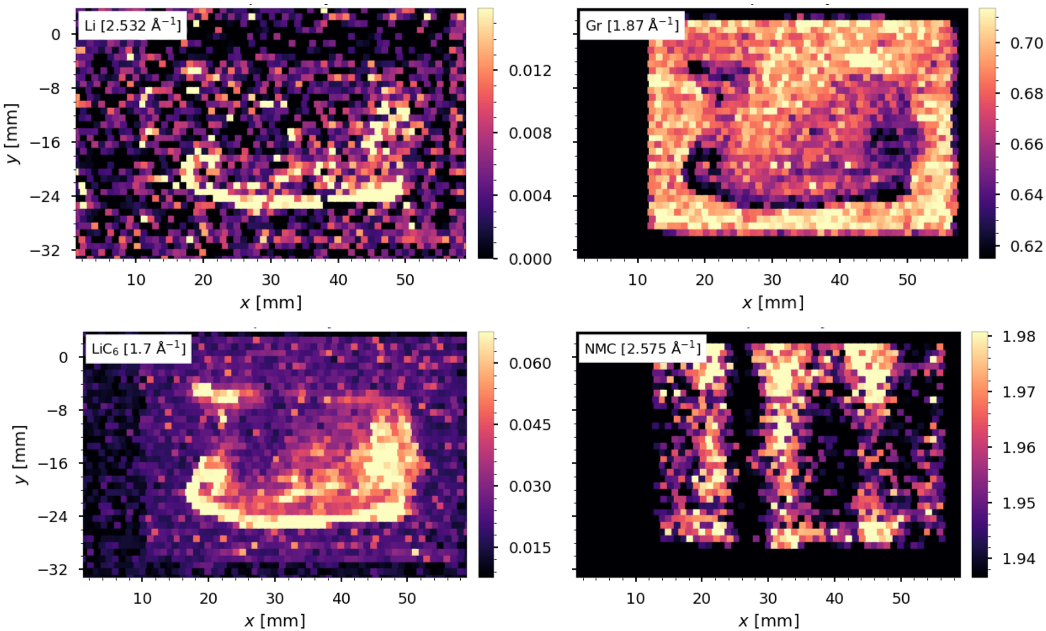
Heterogeneities at all length scales cause early onset of Li plating

length scale		*heterogeneity*
0.1µm		
	Grain	• Crystal anisotropy • Particle-to-particle contact
1µm		
	Particle	• Particle size, morphology
10µm		
	Electrode thickness	• Electrolyte transport limitation leads to plating at electrode surface
100µm		
	Electrode coating	• Porosity/tortuosity variation • Anode overhang
1mm		
	Edge effects	• Electrode misalignment • Electrolyte shorting
1cm		
	Cell	• Dry out, delamination • Pressure • Temperature • Tab configuration
10cm		

Main focus to date

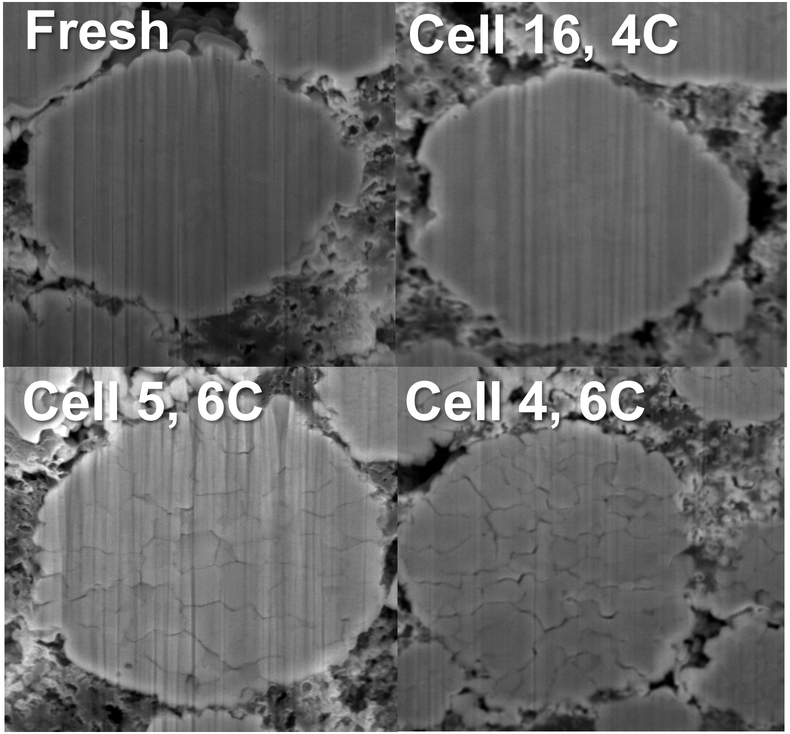
Li DETECTION EFFORTS PROVIDING INSIGHTS

Cycling: 6C, CCCV, 450 cycles



- Intensities of Li and Gr anti-correlated
- Intensities of Li and LiC_6/LiC_{12} correlated
- NMC shows pattern; no obvious correlation with Li

WE ARE ALSO SEEING EARLY EVIDENCE OF CATHODE CRACKING



REMAINING CHALLENGES AND BARRIERS

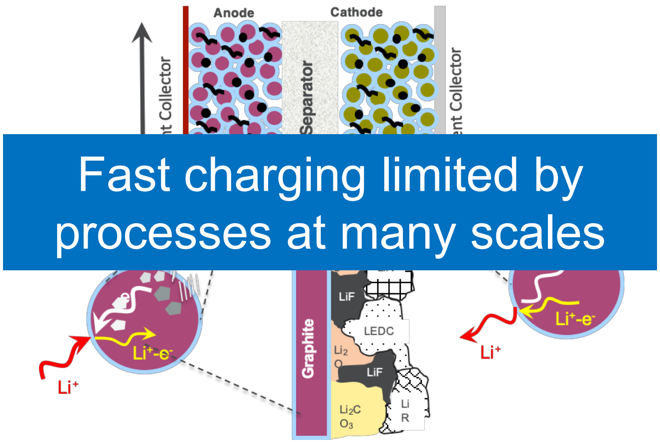
Will be discussed as part of BAT386

PROPOSED FUTURE RESEARCH

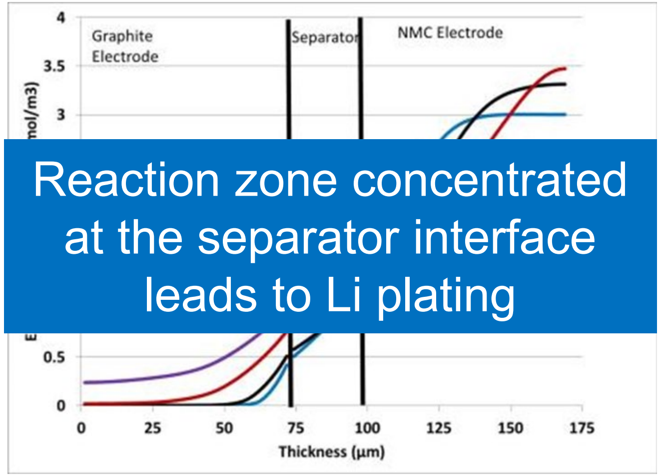
Will be discussed as part of BAT386

Any proposed future work is subject to change based on funding levels.

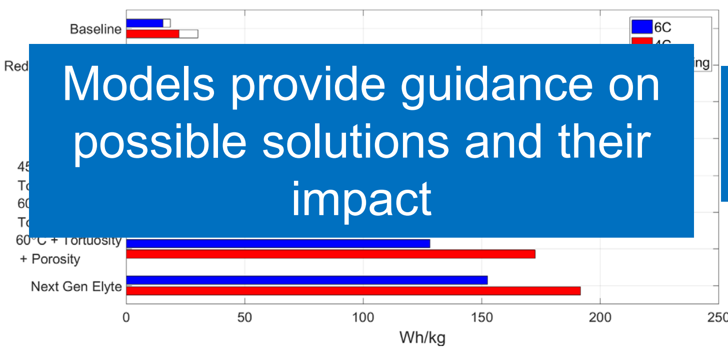
SUMMARY



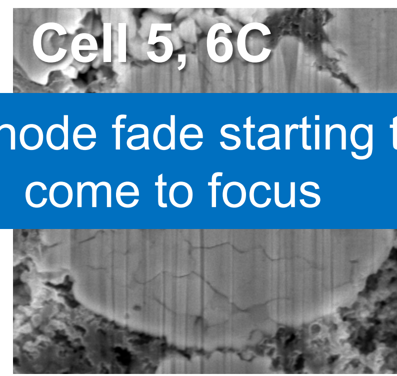
Fast charging limited by processes at many scales



Reaction zone concentrated at the separator interface leads to Li plating



Models provide guidance on possible solutions and their impact



Cathode fade starting to come to focus